AY-141021

ILC SRF Industrialization Cost Sudy:
ILC SRF 工業化コスト検討

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MEXT, ILC-TDR Validation Working Group

28th July, 2014, updated 20th Oct., 2014

この報告の趣旨

- ILC TDR コスト見積もりの中から、最も関心が高く、信頼性評価の核心となる、『超伝導加速空洞システム工業化コスト』について、その評価の為の作業、経緯、結果を重点的に報告する。
  - 詳しいコスト評価内容については、文科省・ILC-TDR 検証作業部会に報告されている。 公式な『非公開情報』となり、慎重な取り扱いを、文科省から求められている。

- また、このコスト見積もりの信頼性を高め、実現する為には、なにが求められるかを、提言する。

アウトライン

- イントロダクション
- 工業化への国際分担基本方針：
- コスト評価作業のプロセス
- コスト評価結果
- コスト評価結果・実現への道、提言

ILC 加速器建設経費 (ILCUを日本円で換算) → 試算モデル

※ Premium (プレミアム：TDR 時点の見積不定性)
- Value Premium: 26%, Labour Premium: 24%

日本円換算コスト(十億円) プレミアム分(十億円) 人件費(百万人時)

	Value Site specific (BILCU)	Value Shared (BILCU)	Value Total (Ratio)	Value Total (BILCU)	Value Prem.: 26% (BILCU)	Value converted (BJY)	Value Prem.: 26% converted (BJY)	Labor (M p-hr)	Labor Prem.: 24%
RDR-2007 Converted w/ 117 Y/$			(1)	6.31		739		24.4	
RDR-2012 (15% inflation)			(1.15)	7.27		877		24.4	
TDR-Averaged	1.50	6.28	(1.23)	7.78					
TDR-AS (ppp)	1.76 (109/127Y/$)	6.23 (127 Y/$)	(1.26)	7.98	2.04	967*	251	22.9	5.5
TDR-AS (EX-a)	CFS 1.76 (109/127Y/$)	3.47 (3.47G$) (100Y/$) 2.75 (2.49GEu) (115Y/Eu)	(1.26)	7.98		830 (8,300億円)	216 (2,160億円)	22.9 (1,598億円)	5.5 (384億円)

TDRコスト(GDE作成)

日本で全て製造した場合に相当 (PPP換算)

日本で予算執行(国際入札)した場合に相当(為替換算)
@ 100 JYen/USD
@ 115 JYen/Euro

SRF（本報告の焦点）

Notes; *TDR Cost : PPP indices used for TDR-Value to Convert to JYen (Jan. 2012)
- JY per USD: 127 (non-civil-construction) , 109 (civil-construction)
- JY per EU: 137 (non-civil-construction), 116 (Civil-construction)

From TDR_Cost_ver4'-130605b/.pptx

A2: ILC TDR Cost： Conversion to Japanese Yen using a model

※ Premium (Uncertainty in TDR value/labor estimate, and to be prepared for unknown situation)

不定性として考えるべき範囲： コスト、人員、期間見積もり等の改訂に伴う

- ➢ Value Premium ; 26%
- ➢ Labour Premium; 24%

TDR cost (by GDE)

Cost based on PPP (full production in Japan)

Cost base on exchange rate Using a model at **1USD=100Yen, 1Euro=115Yen**

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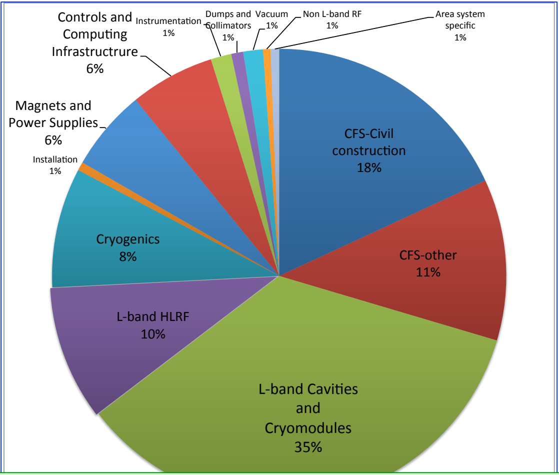
ILC Accelerator Cost Fraction



ILC Accelerator Cost for Asian Site: 7.98 BILC

CFS: 29 %

Civil: ~ 18 %

Others: ~ 11%

SCRF 53 %

Cavity & CM : ~ 35 %

Cryogenics: ~ 8 %

HLRF: ~ 10 %

A technical model for studying specially on industrialization/mass-production scale;

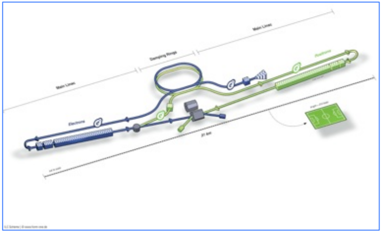
- Host Country : CFS ~ 100%, SCRF ~ 30 % → Total fraction ~ 50 %

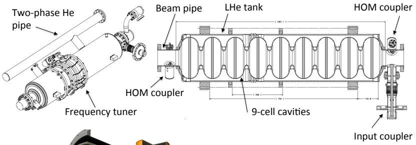
ILC-TDR Accelerator Parameters

Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.5 x10^{34} cm^{-2}s^{-1}
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
Av. field gradient	31.5 MV/m +/-20% **Q_0 = 1E10**
# 9-cell cavity	16024 (x 1.1)
# cryomodule	1,855
# Klystron	~400

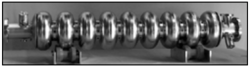
Construction Period for Cavity and CMs

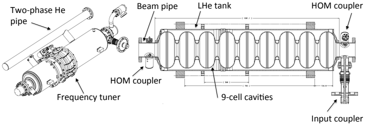
- Preparation + Full-production: ~ 6 years





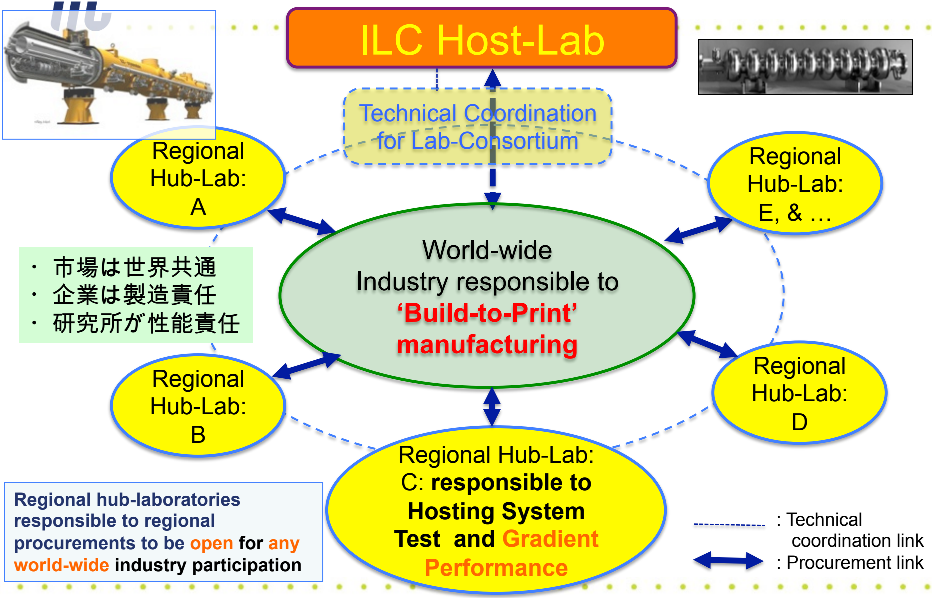
Cavity/Cryomodule Fabrication
空洞･CMの製造





- Purchasing Material/Sub-component
- Manufacturing Cavity：機械加工
- Processing Surface：表面処理
- Assembling LHe-Tank ：組み立て
- Qualifying Cavity, 100 %：性能評価
- Cavity String Assembly：多連空洞組立
- Cryomodule Assembly:: CM 組立
- Qualifying CMs, 33 + 5 %：CM性能評価

SCRF Procurement/Manufacturing Model



Progress in 1.3 GHz 9-cell Cavity Production

year	Capable Lab.	Capable Industry
2006	1 DESY	2 ACCEL, ZANON
2011	4 DESY, JLAB, FNAL, **KEK**	4 RI, ZANON, AES, MHI,
2012	5 DESY, JLAB, FNAL, **KEK,** Cornell	5 RI, ZANON, AES, **MHI, Hitachi**

- One Lab (2 vendor) in 2006, and
- 5 Lab (5 vendor) in 2012 may handle it

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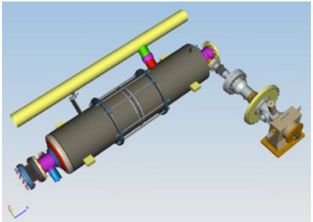
SCRF R&D and Industrialization Study

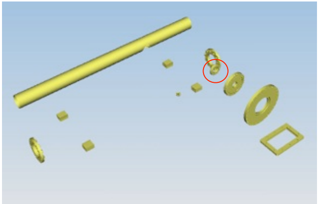
Year	07	2008	2009	2010	2011	2012
Phase	TDP-1				TDP-2	
Cavity Gradient in v. test to reach 35 MV/m	→ Yield 50%				→ Yield 90%	
Cavity-string to reach 31.5 MV/m, with one-cryomodule		Global effort for string assembly and test (DESY, FNAL, INFN, KEK)				
System Test with beam acceleration			FLASH (DESY) , NML (FNAL)STF2 (KEK)			
Preparation for Industrialization	工業化準備			Production Technology R&D		
Communication with industry:	2009: Visit Venders (2009) 2010 -2011: Organize Workshop (2010) 2011: Send specification & receive response 2011~2012: Specific study w/ qualified companies in contracts					

工業化検討・コスト評価のプロセス

2008 ~ 2010	技術開発→工業化プロセス基本方針の策定 - "Plug-Compatibility" を基本とした国際分担	P.C.: LCWS-2008 (Chicago)
2009 ~ 2010	企業訪問・意見交換・コスト検討（無償見積）	Hitachi, MHI, RI, Zanon, AES, Niowave, PAVAC
2010 ~ 2011	国際会議でのIndustrialization Workshop(s)の開催、企業との公開・意見交換	2010: IPAC-2010 2011: SRF-2011
2011 ~ 2012	更なる企業訪問、意見交換 工業化検討（契約）・コスト評価	訪問：19社 Cavity: RI, MHI, CM: BN, Hitachi QMag: Toshiba
2012	TDR へのコスト評価	TDR and Cost Estimate Document
2013 ~	Project 準備：工業化技術、最適化検討、検証	In progress

Plug-compatible Conditions





Item	Variation	TDR Baseline
Cavity shape	TESLA / LL	TESLA
Length		Fixed
Beam pipe flange		Fixed
Suspension pitch		Fixed
Tuner	Blade/ Slide-Jack	Blade
Coupler flange (cold end)	40 or 60	40 mm
Coupler pitch		Fixed
He –in-line joint		Fixed
Magnetic shield	Inside/outside	Inside

Plug-compatible interface established

Communication w/ Industry
in 2009 - 2011

Visits to SC Cavity Manufacturers in Global Industry: 2009

Notes:
AES: Advanced Energy Systems
RI: Research Instruments (previously, ACCEL)
MHI: Mitsubishi Heavy Industries

Visits to Industry in 2009

A Satellite Meeting at IPAC-2010

SCRF Cavity Technology and Industrialization

Date : May 23, 2010, a full-day meeting, prior to IPAC-2010
Place: Int. Conf. Center, Kyoto, Japan
Organized by: ILC-GDE Project Managers,

The 2nd workshop on SCRF Technology and Industrialization for the ILC

as a satellite meeting of SRF 2011

- Date: July 24, 2011
- Place: Chicago
- Agenda:
  - Introduction
  - Reports from SCRF cavity/cryomodule industry
  - Reports from SC material vendor
  - Comments from Potential Regional Hub-laboratory
  - Discussions on the ILC SCRF industrialization model
- Note:
  - Open for everybody,
  - Many Industrial participations acknowledged

Twice Industrial Workshops:
Industry invited

国際的工業界との２回に亘るワークショップ
意見交換を開催：2010~2011

Communication with Industry, in 2009-2013

企業訪問･工業化検討協力

	Year	Company	Place	Technical subject
1	2009~2012	**Hitachi**	Tokyo (JP)	Cavity/Cryomodule (CM)
2	2009~2012	**Toshiba**	Yokohama (JP)	Cavity/CM, SC Quadrupole
3	2009~2012	**MHI**	Kobe (JP)	Cavity / CM
4	2011~2012	Tokyo Denkai	Tokyo (JP)	SC Material
5	2011	OTIC	NingXia (CN)	SC Material
6	2009 - 2011	Zanon	Schio (IT)	Cavity/CM
7	2009~2012	**RI**	Koeln (DE)	Cavity, Coupler
8	2009~2012	**AES**	Medford, NY (US)	Cavity
9	2009-2011	Niowave	Lansing, MI (US)	Cavity/CM
10	2009, 2012	PAVAC	Richmond, BC (CA)	Cavity
11	2011	ATI Wah-Chang	Albany, OR (US)	SC Material
12	2011	Plansee	Ruette (AS)	SC Material
13	2011	SDMS	Sr. Romans (FR)	Cavity
14	2011~2012	Heraeus	Hanau (DE)	SC Material
15	2011~2012	**Babcock-Noell**	Wurzburg (DE)	CM assembly
16	2011	SST	Maisach (DE)	EBW
17	2012	Toshiba Electron-Tube	Nasu (JP)	HLRF (Klystron, Coupler)
18	2012	Thales	Velizy Villacoublay (FR)	HLRF (Klystron)
19	2013	Wuxi City Creative Chemical Equip. (CX)	Wuxi (CN)	CM / Cryomodule components

URL site: prepared for

visiting
SCRF Cavity Manufacturers

共通の説明・技術仕様を示し、
コスト見積もりを依頼

ILC Global Design Effort Project Manager visit to SCRF ca... http://www.linearcollider.org/cms/?pid=10006

international linear collider

ILC Global Design Effort Project Manager visit to SCRF cavity manufacturers

February - March 2009

In early 2009 the ILC Global Design Effort Project Managers (Akira Yamamoto, Marc Ross, and Nick Walker) visited and were graciously hosted by many of the world's top superconducting RF cavity manufacturers. The objective of the visit was to:

1. Learn industrial status and possible future at cavity manufacturers.
2. Communicate the ILC GDE Technical Design Phase R&D Plan.
3. Request further industrial R&D effort, particularly to improve "field gradient" and "cost effective production" in order to prepare for the industrialization (mass production).
4. Establish close communication and a confident relationship between ILC GDE and vendors.

This web page is intended to capture the material presented to vendors and to include key references.

Global R&D Effort of SCRF Cavity Development for the International Linear Collider (pdf, 5Mb)
Akira Yamamoto, Marc Ross, and Nick Walker - Project Managers for the ILC Global Design Effort, **material presented to each of the SCRF cavity manufacturers.**

Superconducting RF Cavity Development for the International Linear Collider (pdf, 4Mb)
Akira Yamamoto for the ILC Global Design Effort, **paper presented at Applied Superconductivity Conference 2008 (ASC 2008).**

Global R&D effort for the ILC linac technology (pdf, 4Mb)
Akira Yamamoto for the ILC Global Design Effort, **paper presented to EPAC 2008.**

Reference Design Report

Download the full report

Volume 3 - Accelerator:
Download the pdf (20MB)

ILC Research and Development Plan for the Technical Design Phase

Download the pdf

(Last updated: 25 February 2009)

工業化における責任分担

- Industry: manufacture/vendor → 製造に責任
  - Fabricate components based on "build to print" specification :
    - Minimizing risk in industrial cost and maximizing cost-effective mass production
- Laboratory (Hub-laboratory) → "性能に責任"
  - Qualify components, such as cavities, and cryomodules,
    - Requiring major test facilities
  - Responsible for the performance of the deliverables to the ILC host-laboratory

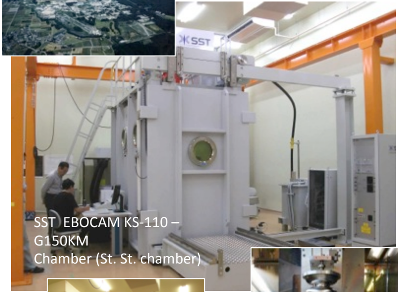
A Model for Cavity and CM Production and Qualification Process

空洞とクライオモジュール製造と性能評価

Step hosted	Industry	Industry/ Laboratory	Hub-laboratory	ILC Host-laboratory
Regional constraint	no	yes or no	yes	yes
Sub-comp/material - Production/Procurement	Nb, Ti, specific comp. …		Procurement	
9-cell Cavity - Manufacturing	9-cell-cavity, Process, He-Jacketing		Procurement	
9-cell Cavity - Performance Test			Cold, gradient test	
Cryomodule component - Manufacturing	V. vessel, cold-mass ...		Procurement	
Cryomodule/Cavity - Assembly		Cav-string/ CM-assembly		
SCRF Cryomodule - Perofrmance Test			Cold, gradient test	
Accelerator integration, Commissioning				Accelerator sys. Integ.

研究所（自ら）：製造・工業化技術開発に努力

EBW



SST EBOCAM KS-110 –
G150KM
Chamber (St. St. chamber)

Press

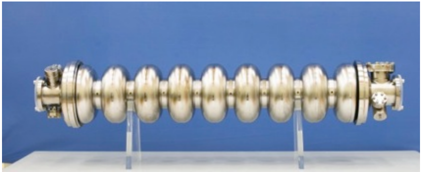
AMADA digital-survo-press
SDE1522
150t, 50stroke/min,
225mmstroke

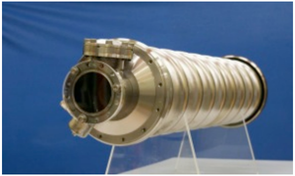
Trim

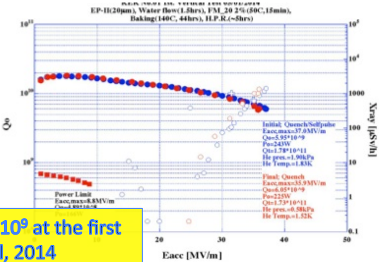
MORI VKL-253
Vertical CNC lathe

Chemical process

KEK (in-house) 9-Cell Cavity (KEK-01) completed, and tested, April, 2014



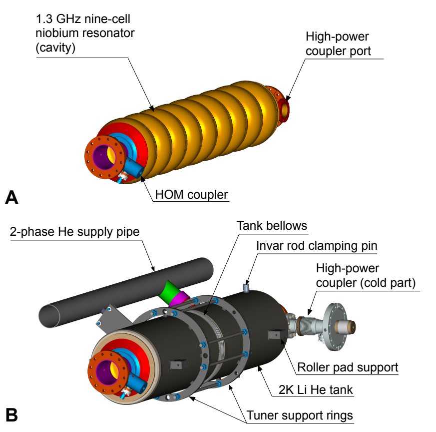




Reached 36 MV/m at Q = 7 x10^9 at the first vertical RF Test at 1.9 K, April, 2014
１号機で、ILC 要求を(ほぼ)達成

N. Walker

1.3 GHz 9-Cell Cavities/Resonators



Ultra-Clean Environment Required for assembly

Solid high-grade niobium
- **RRR ≥300**

Mechanical fabrication
- **deep drawing**
- **electron-beam welding**

Surface preparation
- **electro-polishing**
- **High-pressure rinsing**
- **800 deg C bake**

Following EXFEL cavity “biuld-to-print” Specification, as reference

Cavity package:
- **HOM couplers (x2)**
- **Magnetic shield**
- **High-power input coupler**
- **Ti-Nb Helium tank (cryostat)**
- **Mechanical tuner**

Courtesy:W. Singer

Reference for Cavity Specification
空洞の参考製造仕様(見積条件)

- **Technical guideline for ILC-GDE TDR and the cost estimate:**
  - referring Specifications for EXFEL1.3 GHz Cavity, issued by DESY: acknowledged!
    - EXFEL/001 and associated documents :Rev.B, June 2009, by courtesy of W. Singer (DESY-XFEL)),
    - The reference specification is available with ILC-GDE PMs, under permission of W. Singer (DESY-XFEL)
    - URL: http://ilcagenda.linearcollider.org/event/ILC-SCRF-TR

W. Singer

VALID DOCUMENTS
FOR THE
SERIES MECHANICAL FABRICATION
OF
SUPERCONDUCTING 1.3GHZ CAVITIES
FOR THE
EUROPEAN XFEL

(XFEL/001)

REVISION B / JUNE 23, 2009

(scrf-treq)

XFEL/001

VALID DOCUMENTS

Number	Title	Revision
XFEL/001	Valid Documents for the Series Mechanical Fabrication of Superconducting 1,3 GHz Cavities for the European XFEL	B
XFEL/002	Technical Specifications for the Series Mechanical Fabrication Superconducting 1,3 GHz Cavities for the European XFEL	B
XFEL/003	Quality Assurance and Quality Control Specifications	B
XFEL/004	Descriptions, Abbreviations, Drawing and EDMS numbers	B
XFEL/005	Helium Leak Tests	B
XFEL/006	Special Tools and Equipements	B
XFEL/007	Technical Specifications, Niobium Material	B
XFEL/008	Technical Specifications, Nb55Ti Alloy	B
XFEL/009	Flow Chart Dumb-Bell Production	B
XFEL/010	Recommendations for the Machining of Niobium and Niobium-Titanium	B
XFEL/011	Recommendation for the Treatment of Niobium Parts (Handling, Cleaning, Etching, Welding)	B
XFEL/012	Overview List and Detailed Inspection List of Tests and Demonstrations	B
XFEL/013	Scanning of Niobium Sheets (Round Blanks)	B
XFEL/014	Frequency Measurement on Dumb-Bell, Half Cell, End Group and Cavity	B
XFEL/015	Technical Specifications for the Series Production of Helium Tanks	B
XFEL/016	Technical Specifications for Welding the Helium Tank to the Cavity	B
XFEL/017	DESY Work Instructions for Welding a Cavity into a Helium Tank	B
XFEL/018	Standards	B

数百ページに及ぶ詳細な
実計画入札の仕様を基準として
見積もり検討を依頼

Cavity and CM Industrial Studies: contracted in 2011-2012（赤印: 契約を伴う量産コスト検討）

	Company	Mass production model	Contract funded by	Notes
Cavity	**RI**	100% →50%	DESY	Entirely new approach for mass production
	AES	20 %	DOE/Fermilab	Extension of current production model
	MHI	20, 50, 100%	KEK	
Quadrupole	**Toshiba**	100% →50 %	KEK	Entirely new approach Conduction cooled magnet
CM & assembly	**Hitachi**	20, 50, 100%	KEK	
	AES	25%	DOE/Fermilab	
	BNG	100%→33 %	CERN	Entirely new approach

EXFEL experience kindly informed, in parallel, by **DESY/INFN, CEA/Saclay**

Study History and Our Proposal

Tesla, ILC-RDR, TDR への検討経過

	Tesla	ILC-RDR	ILC-TDR
Regional/Global	DESY centered effort	Based on global contribution	Based on global contribution
Sub-components	Rely on world-wide market	Rely on world-wide market	Rely on world-wide market
9-cell cavity mechanical fab.	**Single vendor （単企業）**	**Single vendor （単企業）**	**Two vendors assumed（複数企業）**
Cavity performance test	Tested at DESY	Tested at ILC host-lab	Shared w/ hub-laboratories
Cryomodule component	To be understood	Toe be understood	**Two vendors assumed**
Cryomodule assembly	Single vendor or contract	Single vendor or contract	**Three vendors assumed**
Cryomodule performance test	Tested at DESY (1/3 test?)	Tested at ILC host-lab (1/3 test)	1/3 of CMs to be tested, and shared w/ hub-laboratories

IPAC14: Courtesy: H. Weise

European XFEL

An Accelerator Complex for 17.5 GeV

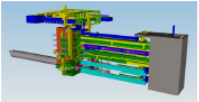
100 accelerator modules

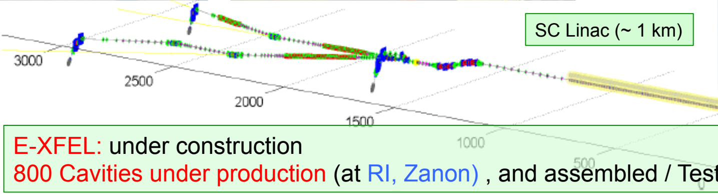
Some specifications

- Photon energy 0.3 - 24 keV
- Pulse duration ~ 10 - 100 fs
- Pulse energy few mJ
- Superconducting linac. 17.5 GeV
- 10 Hz (27 000 b/s)

800 accelerating cavities
1.3 GHz / 23.6 MV/m

25 RF stations
5.2 MW each





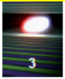
SC Linac (~ 1 km)

E-XFEL: under construction
800 Cavities under production (at RI, Zanon) , and assembled / Tested at CEA-Saclay, D

European XFEL

100 s.c. Modules for the European XFEL

An Accelerator Complex for 17.5 GeV

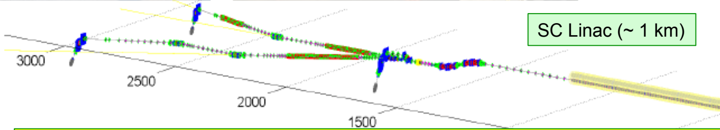


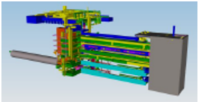
100 accelerator modules

Some specifications
- Photon energy 0.3 - 24 keV
- Pulse duration ~ 10 - 100 fs
- Pulse energy few mJ
- Superconducting linac. 17.5 GeV
- 10 Hz (27 000 b/s)

800 accelerating cavities
1.3 GHz / 23.6 MV/m

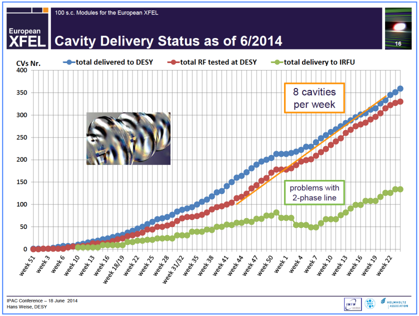
25 RF stations
5.2 MW each





EXFEL: 1/20 Scale Project on going, Industrialization being verifie

SCRF Cavity Production

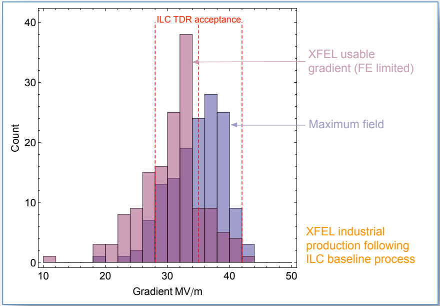


- **Gradients** in average above specification (almost 300 cavities tested)
  - Average usable gradient after delivery (26.8 ± 7.1) MV/m
  - 2/3 of cavities can be used w/o further treatment
  - 1/3 is getting additional treatm. -> usable grad. increased to (29.6 ± 5.1) MV/m

2014.6: # cavities produced > 300. Usable Gradient: ~ < 30 > MV/m

IPAC14: Courtesy: N. Walker

SCRF Cavity Production



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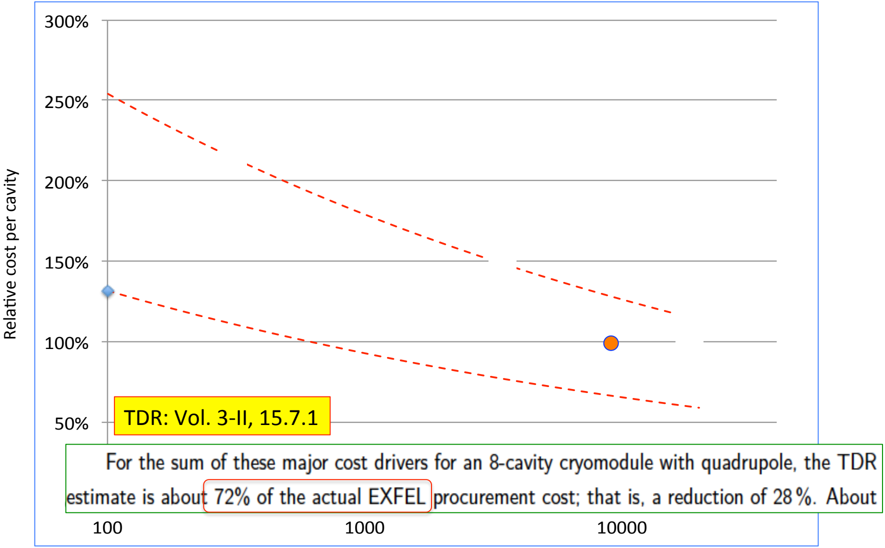
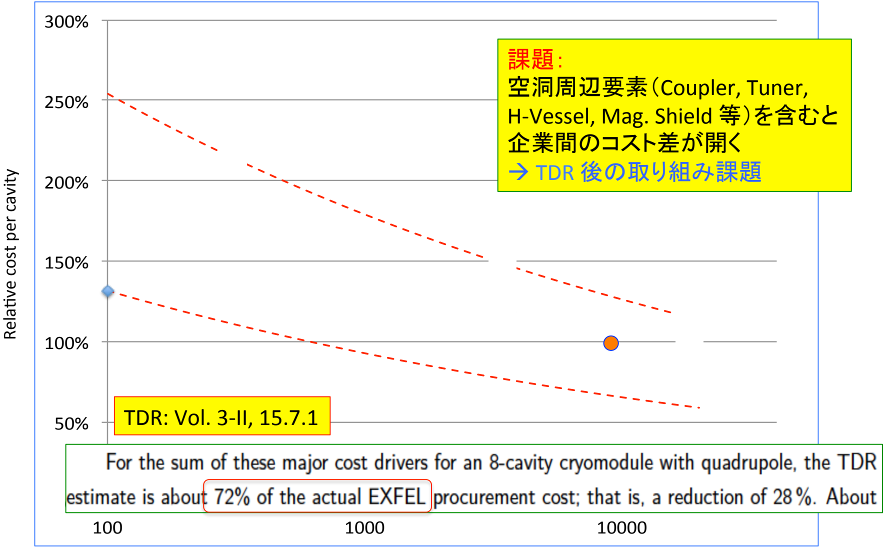
超伝導加速空洞・工業化コスト評価の推移



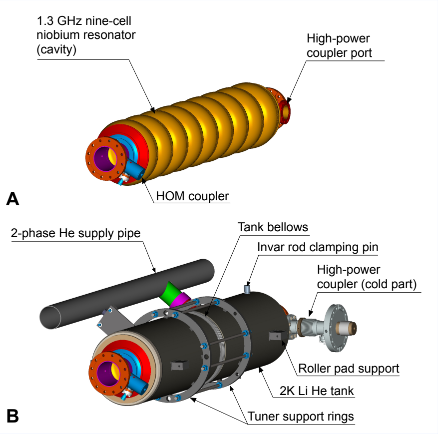
超伝導加速空洞・工業化コスト評価の推移



アウトライン

- イントロダクション
- 工業化への国際分担基本方針:
- コスト評価作業のプロセス
- コスト評価結果
- コスト評価結果・実現への道、提言

1.3 GHz 9-Cell Cavities/Resonators



Solid high-grade niobium

- RRR ≥300

Mechanical fabrication

- deep drawing
- electron-beam welding

Surface preparation

- electro-polishing
- High-pressure rinsing
- 800 deg C bake

We need to look at these, now

Cavity package:

- HOM couplers (x2)
- Magnetic shield
- High-power input coupler
- Ti-Nb Helium tank (cryostat)
- Mechanical tuner

今後の課題

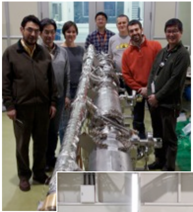
- 周辺機器を含めた、Cavity Integration のコスト評価が課題
  - 空洞本体のと周辺機器の製造（加工）コストは同レベル。
  - Cost Effective な設計が求められる。

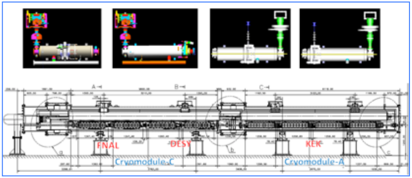
• Cavity Integration	1.00
• 超伝導材料	0.2x
• 空洞本体　：	0.1x
• 空洞表面処理：	0.2x
• カプラー:	0.2x
• チューナー:	0.0x
• He容器:	0.0x
• 磁気シールド:	0.0x

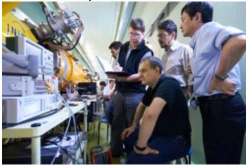
S1-Global hosted at KEK:
Global cooperation to demonstrate SCRF system


DESY, FNAL, Jan., 2010


DESY, Sept. 2010


INFN and FNAL Feb. 2010




FNAL & INFN, July, 2010


March, 2010


DESY, May, 2010


June, 2010 ~

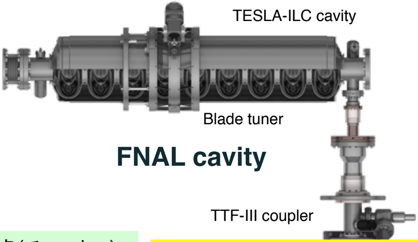
H.Hayano

S1-Global Cavity Packages

エンド部が長くなる

利点：
チューナ構造が単純
HE 容器が単純

TESLA-ILC cavity



Blade tuner

FNAL cavity

TTF-III coupler

TESLA-XFEL cavity

Lever-arm tuner

DESY cavity

TTF-III coupler

利点（チューナー）：
モーターを外に
引き出し

どの設計も、ILC の要求を達成できることを相互に確認

TESLA-like KEK cavity

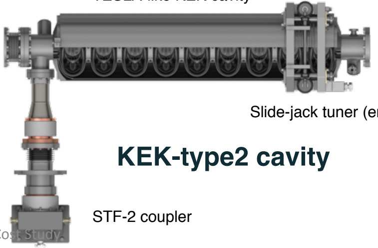
Slide-jack tuner (center)

KEK-type1 cavity

STF-2

利点（カプラー）：
低温部にベローズなし）

TESLA-like KEK cavity



Slide-jack tuner (end)

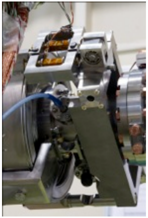
KEK-type2 cavity

STF-2 coupler

Cavities, Tuners, Couplers in S1-G Cryomodule

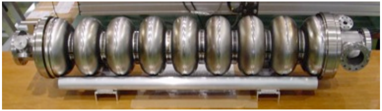
TESLA Cavity (DESY/FNAL)

Blade Tuner (INFN/FNAL)

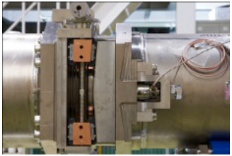


Saclay Tuner (DESY)

TTF-III Coupler (DESY/FNAL/SLAC)



Tesla-like Cavity (KEK)



Slide-Jack Tuner (KEK)

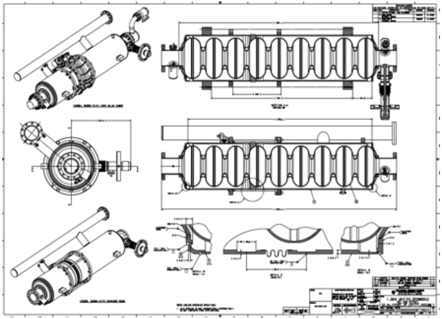
STF-II Coupler (KEK)

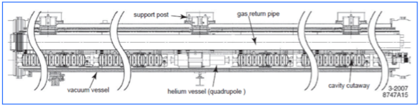
Scope of the Industrial study to be further made

How?

- Analytical cost study, based on EXFEL CM assembly specifications and Work Break-down Structure (WBS)
- But including ILC specificities (see below)

	XFEL	ILC
Configuration:	8 cavities + 1 quad. pkg. in the end.	Type A: 9 cavities Type B: 8 cavities + 1 quad. pkg. in the center.
Cryomodule length: **Quad. pkg. spacing:**	11 142 mm 1 384 mm	11 802 mm 1 327 mm
Cavity length: **Cavity Magnetic shield:** **Tuner-type and location:**	1 256 mm Outside LHe tank Double lever type at end of cavity	1 247 mm Inside LHe tank Blade-type at middle of cavity
Quadrupole magnet **Type:** **Coil length:** **Magnet weight:** **Cooling:** **Assembly with cavity string:**	 Super-ferric ~200 mm ~100 kg LHe bath cooling in clean room	 Iron yoke split magnet ~1000 mm ~ 400 kg conduction cooling outside clean room
5 K radiation shield	Included	Optionally removed

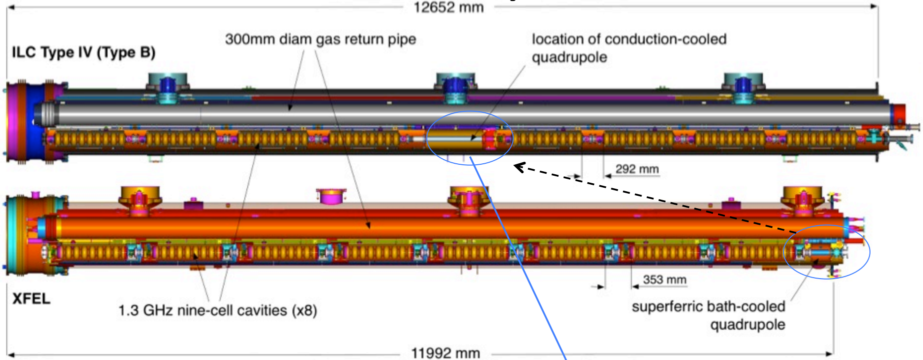


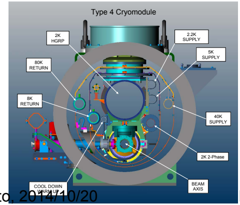


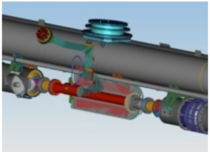
相対コスト(現状):

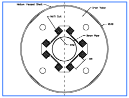
- Coupler: STF > TTF-III coupler (XFEL)
- Tune/He-V: S-Jack >> Blade >> Lever (XFEL)
- Mag. Shield: Inside > Outside (XFEL)

XFEL vs ILC Cryomodule



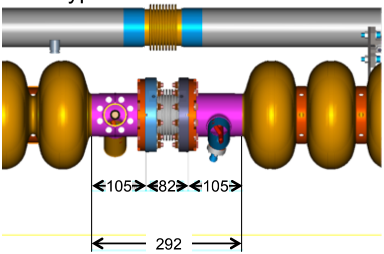


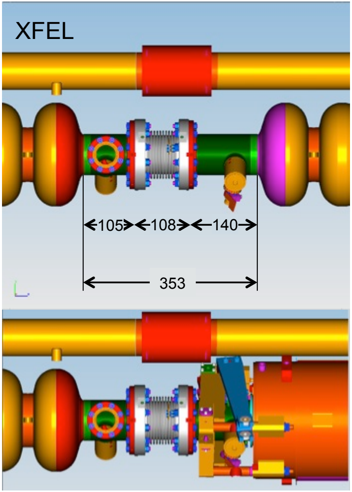




Inter-Cavity Spacing

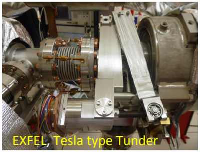
ILC Type-IV

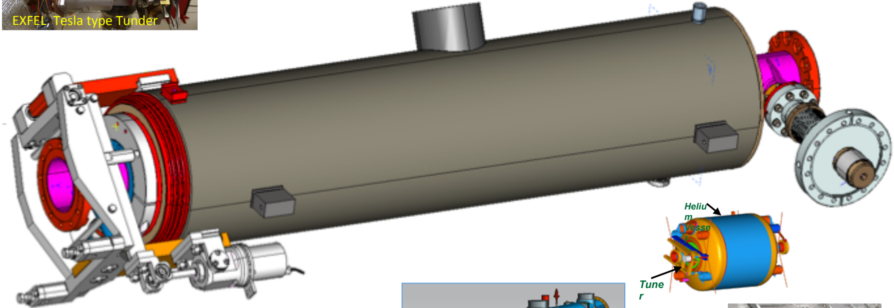




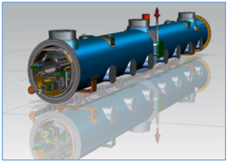
Reduction in inter-cavity spacing		**= 61 mm**
Bellows:	= 108→82	= 26 mm
“Long” cavity end	= 140→105	= 35 mm

LCLS-II Cavity: a Tuner Design Option to be investigated





- LCLS Tuner design covering the beam pipe flanges, overcoming a constraint with a shorter beam pipe
- On the other hand, motor access-ability need to be figured out



SNS: SRF Tuner access-ability demonstrated

コストをコントロールする努力

- **空洞工業化技術の習熟**
  - 工業化技術習熟
  - 周辺機器を含めた最適化
    - Plug-Compatibility の概念を堅持
      - 性能を満たしつつ、コスト・エフェクティブな設計ができる。
      - コストを保ちつつ、性能を向上することができる。

- **一つの可能性**:
  - 空洞にILC cavity (short type) に適応するLever-Tuner を組み込む。
  - クライオモジュールにアクセスフランジを設け保守を可能に。
  - フランジ追加に対応するコス増を、輻射シールド5Kを節約することで吸収する。

ILC Project Cost Overview
ILC 計画・コスト見積もり（作業中）

- Overall project cost for 500 GeV:（500 GeV 加速器建設）
  - including preparation, construction, and operation,
    - 含む項目：準備、建設、運転、（アップグレード）
  - Values converted to JY (with a model: 1 USD= 100 JY, 1EU = 115 JY),
  - Human resource (labor cost) converted JY TBD

    (with a model: 9,000 ~ 5,000 JY per hour, and 1,700 working hours per year).

- Global cost sharing shall be discussed based on the world-wide overall cost

  国際的なプロジェクト総コスト見積もりをベースに国際分担を検討

- Concerning the preparation,（準備段階について）
  - Pre-preparation for 2 years before decision given be carried out by existing R&D budgets, (not included in the overall project cost)

  判断前の予備的な準備段階は、現存の先端技術開発予算、人員で技術開発を継続する

  （プロジェクトコスト一覧には、含まない）
  - Officiall preparation for 4 years after the decision be carried out with a new budget authorized for the ILC preparation ,

  公式な準備期間（建設にむけた判断後）には、新たなプロジェクト準備費想定し、一覧に含む

  （それまでの 技術開発予算・人員は、ILC プロジェクト費用の一部に組み変えられる）

ILC Project Overview : プロジェクト全体像

Years	TDR baseline Scenario
1 - 2	Pre-preparation for 2yrs (for technical effort continuity) 前段階・先端技術開発の継続（2年）
3 - 6	Preparation (4 yrs) ILC 建設への準備段階（4年）
7 - 15	Construction (9 yrs) 建設（9年）
(12 -)	(start installation) 組み込みの開始
(13 -)	(start preparation for Commissioning and operation (to be studied) 運転にむけた準備の段階的立ち上げ (検討要）
16 -	Beam Commissioning start ビームコミッショニング
17 – (30)	Operation at 250 ~ 500 GeV (550 GeV) 物理実験 8250 ~ 500 GeV (550 GeV)
TBD	Toward 1 TeV upgrade 1 TeV アップグレード

ILC Project-Cost Overview (at 500 GeV)

(V- 1410120	Value 10^8 JY	Uncertainty (-/+) %,	JY	Human Resource P-hr	(FTE)	10^8 JY	Uncertainty (-/+) %,	JY	Value+HR 10^8 JY	Range 10^8 JY	See note
Formal Preparation (4 years)											
Accelerator + CFS (for 4 yrs)	TBD			TBD					TBD		A1
Lab. Support. - Land, Load, Lab ...	TBD			TBD					TBD		A1
Detectors	TBD			TBD					TBD		A1
Construction (9 years)											
Accelerator (Acc. Equipm. + CFS) (TDR values)	**8,309** **(5,709+2602)** **(7.98 BILC)**	26%	2,160	22.9 M	**(13,471)**	**1,598**	24%	384	**9,907**	7,363 ~ 12,451	A2
Lab. Support - Safety, Computing, etc	**TBD**			TBD		**TBD**			TBD		A2
Det. Constr (for 9 yrs)	**SiD: 315** **(315 MILC)** **ILD: 451** **(392 MILC)**	--- ---	+127 (+/-48)	--- ---	**(748)** **(1,400)**	**89** **150**	--- ---	--- ---	315+89 = 404 451+150 = 601	404~531 (553~649)	A2
Full Operation (per year)											
Acc. + CFS Operation	**390** **(390 MILC)**	40%	156	---	**(850)**	**101**	25%	25	491	TBD	A3
Lab. Support	TBD			TBD					TBD		
Det. Operation	TBD			TBD					TBD		

まとめ

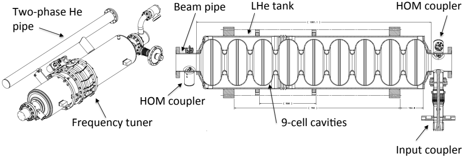
- TDR 加速器コスト評価のまとめ:
  - 加速器（及び施設）建設
    - 物件費 (~ 8,300）＋労務費(~1,600) ＝ ~ 9,900 億円+/- ~ 25 %
  - 運転（＋運営）経費、作業中
    - 物件費 (390+/- TBD)＋労務費 (100 +/- TBD) ＝490 億円 +/- TBD

- 加速器超伝導関連経費は、加速器経費の~2/3 を占めている。
  - その他の経費はRDR での評価（主として、アメリカの研究所での評価）に大きなずれがでた場合にも、その影響は、全体計画に対しては、x 1/3 の効果に抑制される。

- さらに詳細な個々のコスト評価については、今後、更なる取り組みにご協力を頂くべき方々に、別途ご報告する機会（非公開）を頂きたい。
  - 文科省・ILC-TDR検証作業部会での座長決裁と同様に、情報の守秘について、お約束を頂いたうえで、ご報告させて頂くことにご理解、ご協力をお願い致します。

Appendix

SCRF Linac Technology



1.3 GHz Nb 9-cellCavities	16,024
Cryomodules	1,855
SC quadrupole pkg	673
10 MW MB Klystrons & modulators	436 *

* site dependent

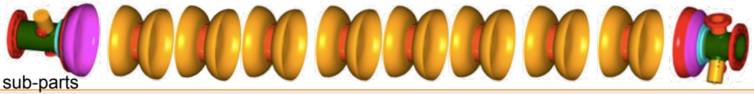
Approximately 20 years of R&D worldwide
→ Mature technology, overall design and cost

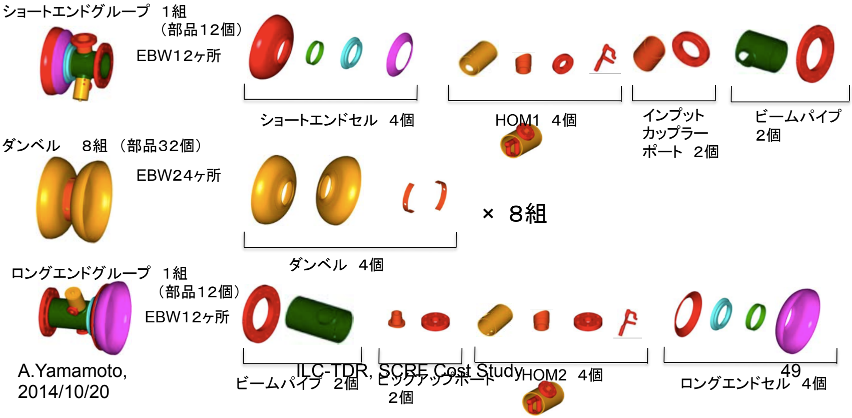
空洞部品の種類と点数

Number of parts of SC Cavity (to be EBW into 10 sub-parts)

総部品点数：56個
10組の部品製作に要するEBW=48ヶ所
電子ビーム溶接(EBW)で行う

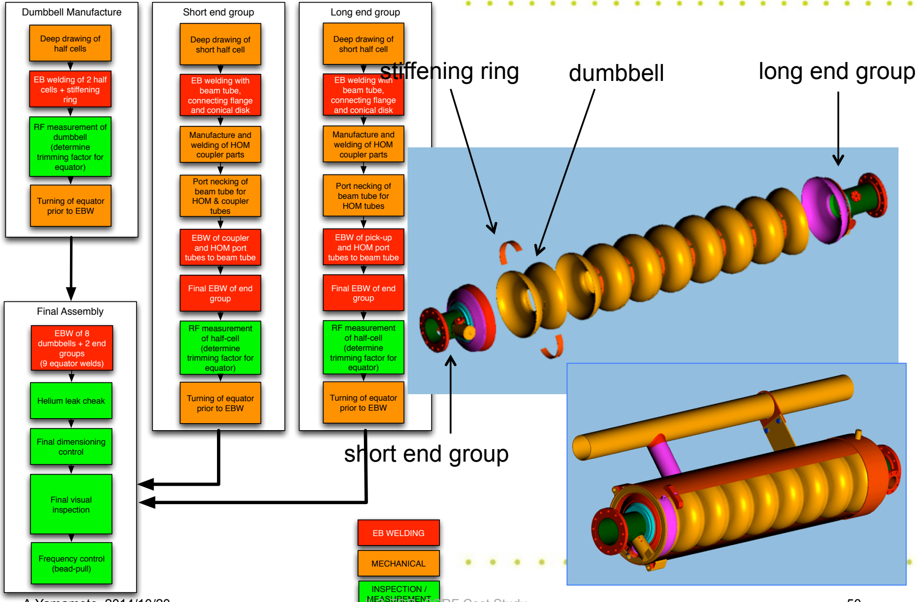
Total number of parts: 56
Number of EBW for 10 sub-parts: 48
EBW=Electron Beam Welding





A.Yamamoto,
2014/10/20

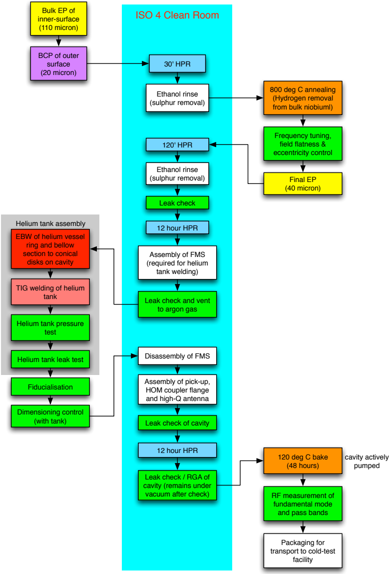
Mechanical Fabrication



Standard Process Selected in Cavity Production and the Yield

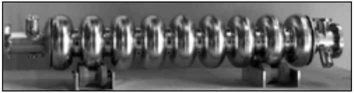
	Standard Cavity Recipe
Fabrication	Nb-sheet (Fine Grain)
	Component preparation
	Cavity assembly w/ EBW (w/ experienced venders)
Process	1st (Bulk) Electro-polishing (~150um)
	Ultrasonic degreasing with detergent, or ethanol rinse
	High-pressure pure-water rinsing
	Hydrogen degassing at > 600 C
	Field flatness tuning
	2nd Electro-polishing (~20um)
	Ultrasonic degreasing or ethanol
	High-pressure pure-water rinsing
	Antenna Assembly
	Baking at 120 C
Cold Test (vert. test)	Performance Test with temperature and mode measurement (1st / 2nd successful RF Test)

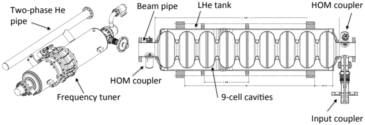
Surface Preparation (XFEL)

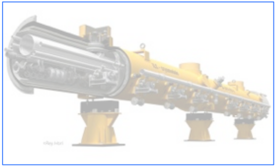


- **Key processes**
  - Electropolishing
    - 110µm, 40µm
  - Ethanol rinse
  - Baking (800° C,120° C)
  - High pressure rinse (HPR)
  - Frequency measurement
  - Pressure testing / leak check
  - Helium tank assembly
- **ISO 4 clean room required**
  - cavity passes 3× through clean room (XFEL spec.)

Cavity/Cryomodule Fabrication
空洞･CM の製造プロセス







- Purchasing Material/Sub-component
- Manufacturing Cavity
- Processing Surface
- Assembling LHe-Tank
- Qualifying Cavity, 100 %
- Cavity String Assembly
- Cryomodule Assembly
- Qualifying CMs, 33 + 5 %